# Invited Paper: Blockchain Governance and Liquid Democracy – Quantifying Decentralization in Gitcoin and Internet Computer

Stefan Schmid
TU Berlin and Weizenbaum Institute, Germany

Dmitry Shestakov
TU Berlin, Germany

## ABSTRACT

Blockchain governance plays a crucial role in projects utilizing blockchain technology, as it defines decision-making and the evolution of the project over time. In this paper, we are particularly interested in liquid democracy governance models which have recently gained attention and which allow to delegate votes. We empirically study existing deployments of these models on Gitcoin and the Internet Computer, and measure the concentration of the voting power. We observe quite a high skew, which contrasts with the otherwise highly decentralized nature of the application. We hope that our preliminary insights can lead to follow-up work in the community and nourish the discussion on the different governance designs.

## CCS CONCEPTS

• **Security and privacy → Human and societal aspects of security and privacy**; • **Computer systems organization → Distributed architectures**; • **Human-centered computing → Collaborative and social computing**.

## KEYWORDS

Blockchain, Decentralization, Governance, Liquid Democracy, Voting Power, On-Chain Analysis

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## 1 INTRODUCTION

Blockchain-based applications such as cryptocurrencies, Web 3.0 and Metaverse, have recently received much attention for their innovative and decentralized solutions. In fact, in many of these applications, not only the blockchain technology itself is expected to be highly decentralized, but also the governance structures that define how the project evolves.

In a nutshell, blockchain governance is a mechanism that enables participants in a blockchain project to vote on proposals that will shape the future development of the project. These proposals may encompass a range of topics, including forks, code changes, the addition or removal of nodes, and other matters.

A governance model which has recently received particular attention is liquid democracy, a hybrid between direct and representative democracy, where the voting power is executed directly or via a mechanism for dynamic representation. This is typically achieved via token delegation which is especially beneficial for the participants with few governance tokens: they can have their interests represented in the project by delegating and not researching all the proposal details by themselves. The Internet Computer (ICP) provides an interesting generalization of such token delegation. Tokens locked for governance are called neurons. Neurons can either vote themselves or follow the decision of one or multiple other neurons, and hence, e.g., be represented by the majority of the followed neurons.

Our paper is motivated by the question to which extent the current governance models achieve decentralized decision making. In particular, while following and delegation may introduce interesting flexibilities and are convenient, it may also result in a concentrated accumulation of voting power and hence in skew and centralization. A disparity in voting power among the governance participants can imply that those holding a larger stake in governance tokens typically wield greater influence.

In this study, we aim to investigate and quantify the extent of centralization of voting power in two different systems: (1) Gitcoin, a leading platform in the Ethereum ecosystem; and (2) the Internet Computer, which offers a decentralized alternative to the current Internet cloud providers. Both systems allow their participants to vote, e.g., on the future of the network with their tokens. We will analyze the distribution of voting power among participants and identify any patterns of centralization that may emerge.

**Context and Previous Research.** Ideas related to liquid democracy (also known as delegative democracy and transitive voting) go back at least to Carroll's *Alice's Adventures in Wonderland* where candidates can transfer received votes to other candidates [1]. A recent real-world example is Germany's Pirate Party which applied delegations for internal voting [2]. Innovative governance structures are often discussed in the context of decentralized autonomous organizations (DAO), member-owned communities and organizations without centralized leadership. DAOs are typically managed in whole or in part by a decentralized computer program, with voting and finances handled through a blockchain.

The stablecoin protocol MakerDAO is an early example of a governance system related to blockchain; it builds upon Ethereum and its value is supposed to be pegged to a reference asset (e.g., the dollar). In general, substantial research has already been made on the key features of blockchain governance [3]. For a systematic literature review we refer to the survey by Liu et al. [4] and the

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Systematization of Knowledge by Kiayias et al. [5] examining the key aspects like the voting system, incentives, security, and timelessness. For an overview of decentralized finance (DeFi) aspects in general, see [6, 7].

An interesting series of blog articles by Vitalik Buterin [8–10] carefully examine the necessity of blockchain governance, especially for Layer-2 projects, and show the drawbacks of the current governance models. Mosley et al. [11] use network analysis to determine the voting patterns, in particular, blockchain governance. Jensen et al. report on an empirical study of governance token distributions [12]. There are also first studies on centralization aspects, e.g., Gochhayat et al. [13] discuss metrics like fairness, entropy, Gini coefficient, and Kullback-Leibler divergence, and Srinivasan et al. [14] introduce the Nakamoto coefficient. However, we are not aware of any work quantifying the decentralization of voting power in the liquid democracy of Gitcoin and the Internet Computer, which is the focus of our work.

Fritsch et al. [15] empirically studied three prominent DAO governance systems on the Ethereum blockchain: Compound, Uniswap and ENS, analyzing how the voting power is distributed in these systems. Barbereau et al. [16] consider the governance systems of nine DeFi protocols: Uniswap, Aave, MakerDAO, Compound, SushiSwap, Synthetix, Yearn Finance, 0x, and UMA. Li et al. [17] study the characteristics of liquid democracy in decentralized governance, considering two major DPoS blockchains, EOS and Steem. They find that liquid democracy has been successfully adopted and that EOS has a more extensive delegation network and more high-degree delegatees, while Steem includes more and longer delegation chains.

**Our Contribution.** We present a preliminary empirical study to quantify the level of decentralization in the liquid democracy governance models of two systems, Gitcoin and the Internet Computer. In these systems, voting is used, e.g., to fund public goods or govern the blockchain of the GitcoinDAO or the Network Nervous System (NNS), a large (on-chain, permissionless) DAO of the Internet Computer. We describe how vote delegations are utilized in these projects, and considering different metrics, we observe a skew in the voting power. We hope that observations motivate further discussions on the implications and design of future governance systems in the community.

## 2 PRELIMINARIES AND METHODOLOGY

To study Gitcoin on-chain governance, we collected on-chain data from the Ethereum blockchain network using Dune Analytics queries [18]; to study Gitcoin off-chain governance (done via the Snapshot platform), we collected the off-chain data with the casted votes for each proposal, using the Snapshot GraphQL API [19]. For the Internet Computer, we have collected the governance information via their public API [20].

In Gitcoin, we distinguish between delegators (the delegating node) and stewards (the delegated node); a delegator may also be a steward for other nodes. We focus on the GitcoinDAO wih the governance token GTC and consider the Gitcoin stewards' own balances and the amount of GTC delegated to them. Specifically:

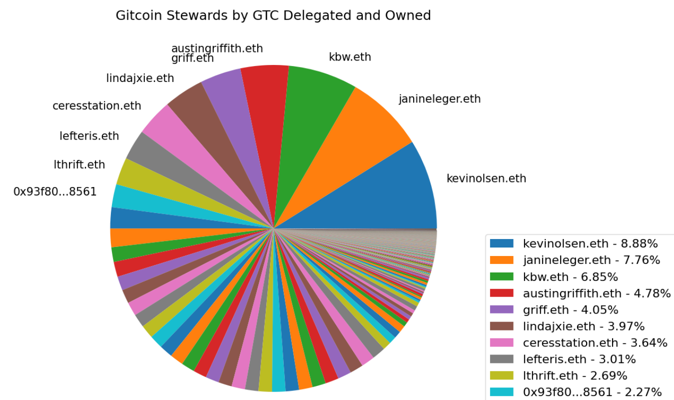


**Figure 1: GitcoinDAO voting power distribution among Stewards. Both delegated and owned GTC.**

- We queried the number of tokens delegated to each delegate from every delegator to obtain the voting power distribution among the delegates and create a directed graph, with nodes representing delegates and delegators and edges representing the voting power delegation.
- We queried the number of tokens held by each address, then removed the addresses that are not participating in the governance and added the delegated tokens to the delegates (as these tokens are technically not held in the delegates' addresses) to obtain the full voting power distribution among the addresses participating in the governance.
- We queried the casted votes for each proposal to determine the proportion of casted votes in the on-chain governance platform Tally [21] for each governance participant.

In the Internet Computer, all changes to the configuration and behavior of are controlled by a governance system called the Network Nervous System (NNS). Internet Computer Protocol tokens are called ICP tokens and are a native utility token with a value determined on the open market. A staked amount of ICP is called a neuron. An interesting unique feature of the Internet Computer is that neurons can follow *multiple* other neurons. We have collected the governance information via their public API.

## 3 EMPIRICAL RESULTS AND INSIGHTS

### 3.1 Token Delegation and Following

We first analyze the token distribution in the Gitcoin project. In our analysis we emphasize the difference between owned and delegated tokens. By owned tokens, we mean the tokens that are held in the address's wallet as, for example, shown in 'Token Holdings' of every address on Etherscan [22]. With delegated tokens we mean the tokens that are delegated, as it is done for example through the Tally [21] platform. This is an important distinction and necessary for analyzing the voting power in a liquid democracy governance model.

Let's start with **GitcoinDAO** and its governance token GTC. Using the on-chain analytics platform Dune, which allows querying

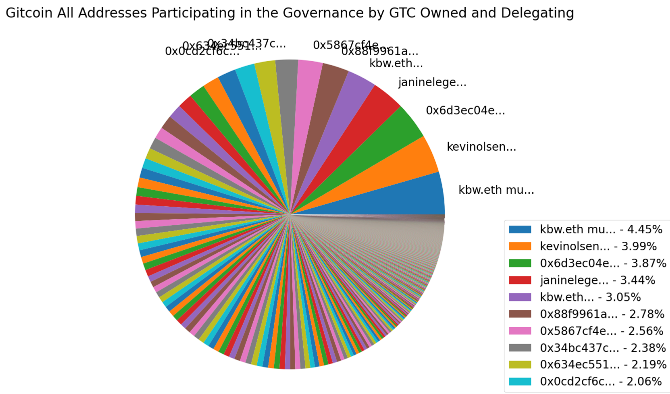


**Figure 2: GTC total voting power.**

blockchain data using SQL queries, we obtain insights about the token distributions for GitcoinDAO. We have collected a data set of all Gitcoin Stewards' own balances and the amount of GTC delegated to them on the 29th of January 2023. With that, we can plot the GTC delegated and owned by each steward by combining the delegated and owned tokens for each steward. Analyzing the voting power among the top stewards is essential, since they do almost all the voting (see later). The resulting chart is shown in Figure 1. In Table 1 the total delegated and owned amount of the GTC tokens are shown for the top 10 stewards. In this analysis, the top-10 stewards control 47.9% of voting power among other stewards, the top-50 control 93.8%, and the top 100 control 96.8% of the total voting power among all stewards.

We next study the GTC distribution among all holders of the token. The GTC token has a total supply of 100,000,000 with its full distribution. This distribution, if taken directly, however, does not reflect the real voting power distribution well due to a number of factors:

- It shows a large amount of locked GTC in the GitcoinDAO Treasury and GitcoinDAO Timelock addresses, that do not currently participate in the governance.
- It does not show the amount of delegated GTC to the stewards, as delegation does not place GTC into the wallet of a steward.

Therefore we have removed the addresses of GitcoinDAO Treasury and GitcoinDAO Timelock from the data and added the delegated GTC to the stewards' addresses and subtracted the GTC from the delegating addresses to find a more accurate distribution of the voting power among all addresses in GitcoinDAO, which is shown in Figure 2. We also removed the address of the Binance 8 wallet and the address of the DAO and token treasuries trust Hedgey, as they do not participate in the governance. It is, however, hard to tell what role some of these addresses play in the voting power distribution. For example, while the largest cryptocurrency exchange Binance 8 holds a large amount of GTC, it is unclear to which extent it can utilize the tokens for voting [23]. This is a major limitation of our current work. From our analysis, we find that the top stewards have a large voting power, despite holding few tokens in their personal wallets.

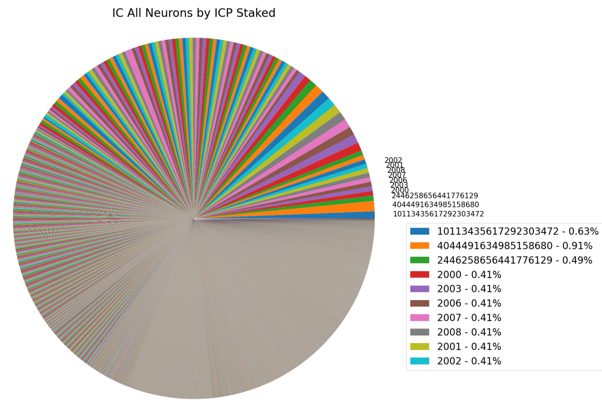


**Figure 3: Distribution of the ICP neurons participating in governance.**

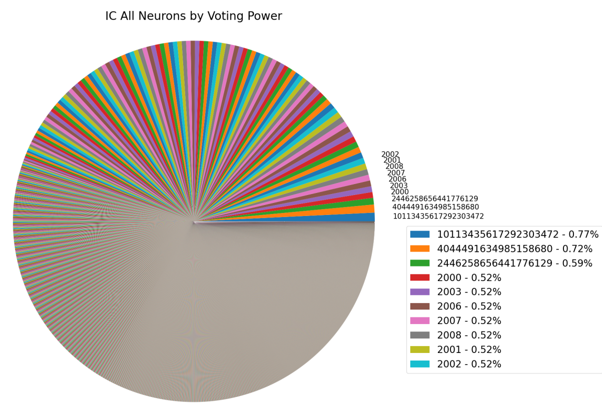


**Figure 4: Distribution of the ICP voting power.**

In the **Internet Computer**, all changes to the configuration and behavior of are controlled by a governance system called the Network Nervous System (NNS). As mentioned above, a staked amount of ICP is called neuron, and a unique feature of the Internet Computer is that neurons can follow *multiple* other neurons. We plotted the distribution of the staked ICP for all known neurons that we queried through their API on the 30th of January 2023. It is important to mention, that a large part of the neurons on the Internet Computer is not indexed and cannot be queried through their API. The governance dashboard states that there are 151,937 [24] neurons in total, while only 18,259 can be indexed through the API [20]. For a neuron to become indexed, it has to be first queried through the API by its id, and there have been proposals for clearer neuron indexing [25].

In Figure 3 we plot the distribution of the ICP neurons participating in the governance. Only neurons in states 'Dissolving' or 'Not Dissolving' whose dissolve delay is more than 6 months can participate in the governance. The total voting power of a neuron can be calculated as the product of the 'Neuron Stake', the 'Dissolve Delay Bonus' and the 'Age Bonus'.

| Steward | Percentage among Stewards | Delegated and Owned Amount (GTC) |
|---|---|---|
| kevinolsen.eth | 8.88% | 1,952,072.97 |
| janineleger.eth | 7.76% | 1,706,263.00 |
| kbw.eth | 6.85% | 1,506,050.79 |
| austingriffith.eth | 4.78% | 1,049,838.39 |
| griff.eth | 4.05% | 891,141.99 |
| lindajxie.eth | 3.97% | 872,130.00 |
| ceresstation.eth | 3.64% | 800,543.00 |
| lefteris.eth | 3.01% | 662,478.30 |
| lthrift.eth | 2.69% | 592,244.00 |
| 0x93f80...8561 | 2.27% | 500,000.00 |

**Table 1: Top-10 stewards by delegated and owned GTC.**

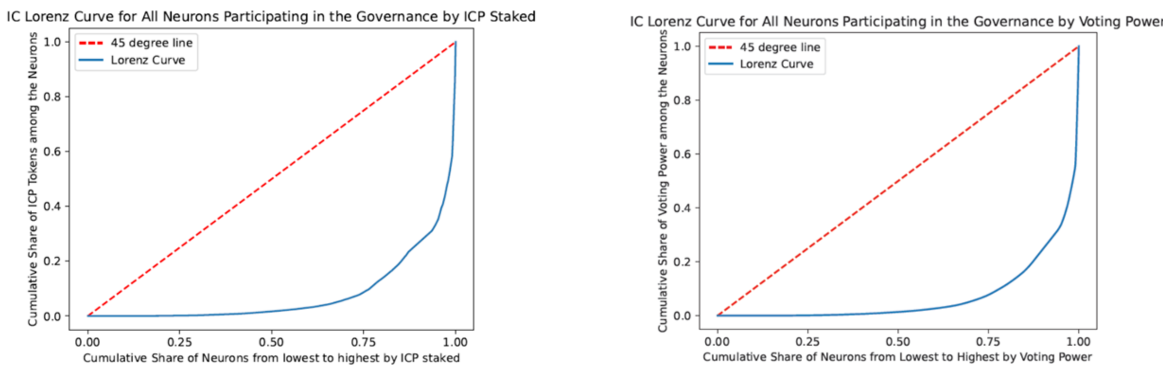


**Figure 5: Lorenz curve for Internet Computer.**

- Neuron Stake: The number of ICP utility tokens staked in the neuron. The distribution is shown in Figure 3
- Dissolve Delay Bonus: A boost to the voting power of up to 100% and a linear function of the dissolve delay. A neuron with a dissolve delay set to the maximum value of 8 years has a 100% dissolve delay bonus. A neuron with a dissolve delay of 4 years has a 50% dissolve delay bonus.
- Age Bonus: The voting power of neurons can be increased by a maximum of 25%, based on their age, with a linear relationship determined by a cap of 4 years. A neuron that has reached the age of 4 years or more would receive a 25% age bonus, while a neuron with an age of 2 years would receive a 12.5% age bonus.

By locking the ICP tokens for a longer time, the voting power can be increased. Hence, neurons which have more 'skin in the game' also get more voting power. We can further quantify the difference between the token and the voting power distributions and show the distribution of the voting power in Figure 4.

The limitation of this analysis is that we cannot consider the follow-related voting power in the NNS. While NNS allows neurons to follow other neurons and automatically vote like the majority of them, the information about the list of followers for every neuron is not public on the IC. The known neurons, such as Neuron 27, named "DFINITY Foundation" and Neuron 28, named "Internet Computer Association" presumably influence a large part of the total voting power because of their followers. A vote of a known neuron for a proposal is often followed by a large spike in total votes for this proposal.

## 3.2 Inequality Metrics

It is common to utilize the Lorenz curve and Gini coefficient, to quantitatively assess the degree of inequality within a population. We plot the Lorenz curves, by first ordering the addresses from the lowest to the highest voting power, and then plotting the cumulative voting power as a fraction of the total voting power against the cumulative number of addresses as a fraction of the number of all addresses. The diagonal line represents the line of perfect equality, where each person would have an equal share of the total voting power. The area between the Lorenz curve and the line of perfect equality represents the degree of inequality in voting power distribution. The Gini coefficient is calculated as the ratio of the area between the Lorenz Curve and the line of perfect equality to the total area under the line of perfect equality.

The Lorenz curve and Gini coefficient show the distribution of a particular resource among the population and have their weaknesses when used in the context of cryptocurrencies, and, especially voting power distributions. In this context, the concentration of resources in the hands of the top few users is a bigger threat for a project, than a very large percentage of the project's users having

**Table 2: Gini and Nakamoto coefficients**

| Figure | Gini coefficient | Nakamoto coefficient |
|---|---|---|
| Gitcoin | 0.992 | 25 |
| Internet Computer | 0.844 | 247 |

very few tokens, as for many users it can just come from the lack of interest for a project [26].

Therefore, we also use another coefficient, called Nakamoto coefficient [14]: the minimum number of entities in a given subsystem required to get to 51% of the total capacity. In our case that is the minimum number of users who possess at least 51% of the voting power or tokens in a given distribution. This coefficient focuses more on the users with the biggest voting power and tells us how many of those would need to collude in order to reach 51% of the total voting power.

For the GitcoinDAO, taking into consideration both delegated and owned GTC for every delegate, for all holders of GTC participating, we observed a very high skew. However, our analysis of the voting power distribution among all addresses, participating in Gitcoin Governance was limited by difficulties in determining which addresses participate in the governance, and which do not, so more research is needed in that area and we do not include the plot here.

For the Internet Computer NNS, we plot the Lorenz curve in Figure 5 for the ICP token distribution among all staking neurons participating in the governance, as well as the Lorenz curve to show the governance power distribution among all neurons participating in the governance.

The calculated Gini and Nakamoto coefficients can be then seen in Table 2. The Internet Computer shows a lower degree of centralization than Gitcoin in our analysis.

### 3.3 Voting

In order to show how voting power is actually being utilized we have analyzed how many votes have been used for being cast by the voters for all proposals. We have queried all proposals, that took place till 28 January 2023. As a reminder, the GitcoinDAO Snapshot is used for off-chain voting on proposals. By the Snapshot vote, the decision for each proposal is ultimately met. If a proposal involves the transfer of funds from the treasury, there is also an on-chain vote through Tally. More information about GitcoinDAO on-chain and off-chain voting can be also found in Table 3.

We find that a very large proportion of votes is cast by the top Stewards. Namely, 73.4% of all Snapshot votes have been cast by the 10 largest voters and 78.5% of all Tally votes have been cast by the top 10 largest voters. Further detailed in Table 4.

For the Internet Computer, the IC API call returns only the last 100 ballots for the neurons that are not known neurons [20]. We do the analysis on the known neurons, since all their votes can be queried since the moment they've become a known neuron. We queried all the votes for the known neurons till the 24th of February and plotted the casted votes distribution among the known neurons. One limitation of this analysis is that the neurons have become known neurons at different times and that influences the number of votes they could have cast so far. Therefore we also queried the data, when the first proposal that each known neuron has voted for was created. It is important to understand the voting of the known neurons, as they have a large number of followers.

### 3.4 A Graphical Visualization

To visualize the relationship between the delegators and stewards, we construct a weighted directed graph of stewards and delegators for the GitcoinDAO. Nodes in this graph have properties of weight and color, the weight of the node is determined by the amount of GTC it receives/delegates. Every edge between two nodes is directed from the delegating node (delegator) to the delegated node (steward). The stewards are colored in green, delegators who are not also stewards are colored in blue, and if the node delegates to itself it is colored yellow.

Figure 6 shows the resulting visualization. We have also only plotted the nodes where the sum of their edge weights is more than 1000 in order to make the graph look less cluttered. From this figure we can see, that the nodes with the biggest weight are mostly stewards, except for the node, which is marked 0xea81...45c5, which is a delegator. We can again see the extent of the voting power that the top stewards, such as kevinolsen.eth, griff.eth and others possess.

## 4 CONCLUDING REMARKS

While our methodologies and results are clearly preliminary, we hope that they can nourish further discussions on the implications and future designs of government systems for blockchains. In particular, if voting schemes tend toward centralization and voter disenfranchisement, explicit but low-overhead incentive mechanisms may have to be designed for a more active involvement of users. This may be especially critical in blockchains where the controlling entities can be obscure. Such incentives may be provided via additional monetary benefits and/or using some form of randomization, perhaps also just in a review process, in order to ensure low overheads, especially for small stake-holders.

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| Voting Platform | Number of Proposals | Total Number of Votes (GTC) | Number of Unique Voters |
|---|---|---|---|
| Tally (on-chain) | 45 | 215,191,152 | 1879 |
| Snapshot (off-chain) | 81 | 417,190,464 | 5295 |

**Table 3: GitcoinDAO on-chain and off-chain voting. Overview of proposals.**

| Voting Platform | % of All Votes among Top 10 Voters | Top 20 Voters | Top 50 Voters |
|---|---|---|---|
| Tally (on-chain) | 78.5% | 95.1% | 99.9% |
| Snapshot (off-chain) | 73.4% | 89.7% | 97.6% |

**Table 4: GitcoinDAO on-chain and off-chain voting. Votes Distribution among the Voters.**

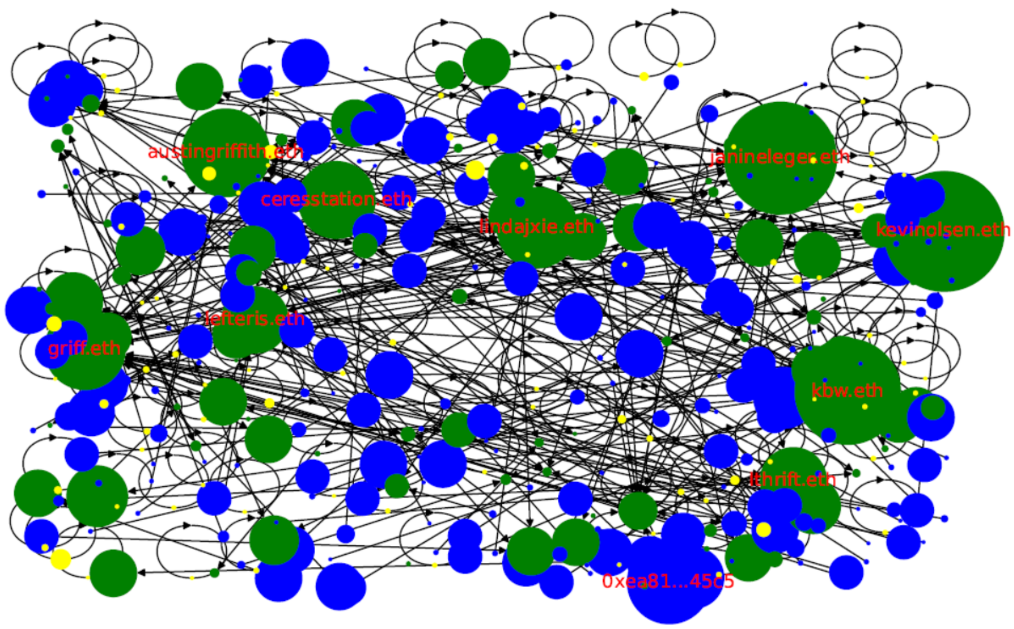


**Figure 6: Graphical visualization of the relationship between the delegators and stewards. The size of a node represents the amount of GTC it receives/delegates, edges are directed from the delegator to the steward. The stewards are colored in green, delegators who are not also stewards are colored in blue, and if the node delegates to itself it is colored yellow. Top stewards, such as kevinolsen.eth, griff.eth and others possess a large amount of voting power.**


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